AAE 590: Space Flight Operations

Instructor: David Spencer
Office: ARMS 3233
Phone: 4-8774
Email: dspencer@purdue.edu
Office Hours: W 1-3 PM or by appt.
TAs: Rohan Deshmukh: deshmur@purdue.edu
Sylvain Renevey: srenevey@purdue.edu

Course Information
Spring 2019
Meeting Times: T/R 10:30 – 11:45 AM
Class Location: Wang 2579
3 Credit Hours

Course Description

Space Flight Operations will provide students with a technical foundation for the operation of Earth orbiting and planetary missions. The course is structured to align with the flight project lifecycle, providing students with the necessary information to design for operability during each phase of project development. The first segment of the course covers mission architecture, including mission concept studies, cost-risk-performance trades, and the use of automation versus human-in-the-loop systems. The second segment introduces mission operations fundamentals, including flight team organization, uplink and downlink processes, risk management, contingency planning, and verification and validation. In the third segment, technical resource budgets will be discussed, including telecommunications link budget, power budget, thermal energy balance, and attitude control system sizing. The fourth segment covers launch operations, flight project practices, and cost estimation. In the final segment, the class will review and discuss failure investigation reports for high-profile mission failures spanning human and robotic missions. Guest lectures will be provided from NASA and industry presenters with experience spanning robotic and human spaceflight.

Prerequisites

This course is open to seniors and graduate students. There are no fixed prerequisites within the AAE curriculum, and the course may be of interest to non-AAE majors.

Learning Outcomes

The Space Flight Operations course is designed so that students will achieve the following learning outcomes:

- Understanding of the terminology associated with space flight operations
- Ability to assess and design mission concept of operations, and understand the implications of the mission architecture to operability
- Development of technical resource budgets, spanning mass, power, thermal, telecommunications, data volume
- Understanding of the roles and responsibilities of a flight team
- Understanding of the processes involved in operating a mission
- Ability to identify and mitigate mission risks

Required Texts

Uhlig, T., Sellmaier, F., Schmidhuber, M., editors, *Spacecraft Operations*, Springer, 1st Edition, 2015, ISBN 978-3-7091-4848-8. This text provides material that is supplementary to the lectures.

Course Requirements

The course requirements include class discussion, reading assignments from the text and additional sources including journal articles, technical reports, and failure investigation documents. Approximately four homework sets will be assigned, and students will submit a term paper. There will be two in-class midterm exams. There is no final exam. Class participation throughout the semester is strongly encouraged.

Policies

General Course Policies

Texting or other electronic communication during class is prohibited. Electronic note-taking is acceptable. Homeworks are due at the beginning of class on the assigned dates.

Grading

Evaluation of student performance in the course will be based upon the following graded work:

Homework assignments (30%)
In-class midterm exams (60%)
Term paper (10%)

Grades will be based upon the following scale. The instructor may choose to adjust the scale based upon the final grade distribution of the class:

A+: 98 – 100%
A: 93 – 97.99%
A-: 90 – 92.99%
B+: 88 – 89.99%
B: 83 – 87.99%
B-: 80 – 82.99%
Etc.

Late homework is not accepted unless previously arranged with the instructor. Make-up exams will only be offered in the event of a pre-arranged absence, or a medical problem with a doctor's note.

Academic Dishonesty

While it is acceptable to consult with classmates regarding homeworks, the work submitted should be your own. Term papers should cite work that is referenced. Plagiarism will not be tolerated.

Purdue prohibits "dishonesty in connection with any University activity. Cheating, plagiarism, or knowingly furnishing false information to the University are examples of dishonesty." [Part 5, Section III-B-2-a, Student Regulations] Furthermore, the University Senate has stipulated that "the commitment of acts of cheating, lying, and deceit in any of their diverse forms (such as the use of substitutes for taking examinations, the use of illegal cribs, plagiarism, and copying during examinations) is dishonest and must not be tolerated. Moreover, knowingly to aid and abet, directly or indirectly, other parties in committing dishonest acts is in itself dishonest." [University Senate Document 72-18, December 15, 1972]

Emergencies
The Purdue homepage (www.purdue.edu) will provide news of campus closures and emergency information. In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Information about these changes will be available from Blackboard and/or via e-mail.

Students with Disabilities
Academic accommodation for students with disabilities must be arranged by the student through Purdue's Disability Resource Center (DRC). The instructor cannot make academic accommodations without a DRC accommodation letter.

Purdue University is committed to maintaining an inclusive community that recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. In pursuit of its goal of academic excellence, Purdue University seeks to develop and nurture its diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas and enriches campus life.

Purdue University views, evaluates and treats all persons in any university-related activity or circumstance in which they may be involved solely as individuals on the basis of their own personal abilities, qualifications and other relevant characteristics.

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Purdue University prohibits discrimination against any member of the University community on the basis of race, religion, color, sex, age, national origin or ancestry, genetic

information, marital status, parental status, sexual orientation, gender identity and expression, disability, or status as a veteran. The University will conduct its programs, services and activities consistent with applicable federal, state and local laws, regulations and orders and in conformance with the procedures and limitations as set forth in Executive Memorandum No. D-1, which provides specific contractual rights and remedies. Any student who believes they have been discriminated against may visit www.purdue.edu/report-hate to submit a complaint to the Office of Institutional Equity. Information may be reported anonymously.

Class Schedule

	Lecture Topics	Reading Assignment or Video Reference	HW, Exams
1/8/18	Syllabus review and course objectives; Course schedule; **The flight project lifecycle**; operations deliverables by mission phase		
1/10/18	**Space mission architecture development:** Morphological matrix; probability chains; system architecture trade studies		
1/15/18	**The space environment:** the vacuum of space; particle radiation; planetary magnetic fields; Van Allen radiation belts; orbital debris	1.1	HW1 assigned
1/17/18	Autonomy vs. ground-in-the-loop; safe mode definition; fault trees; fault protection	2.3, Remote Agent paper	
1/22/18	Concept of operations; Mars Sample Return mission architecture	2.2.4	HW1 due
1/24/18	Human exploration architectures: Lunar gateway; Mars exploration; Mars colonization	https://youtu.be/H7Uyfqi_TE8	
1/29/18	**Flight operations management**: Flight team organization, roles and deliverables; uplink and downlink processes	2.1, 2.2	HW2 assigned
1/31/18	Operations risk management; contingency planning; anomaly response; test & training		
2/5/18	System engineering; requirements definition; the verification & validation process; TLYF, FLYT	1.2	HW2 due
2/7/18	Case studies: Deep Impact, Phoenix Mars Lander		
2/12/18	Review		
2/14/18	Midterm 1		
2/19/18	**Space communications**: Tracking, telemetry and commanding; tracking station operations, critical event coverage	3.2	
2/21/18	**Technical resource budgets**: Contingency and margin; Mass budget, DV and propellant budget; Telecommunications link budget; Data volume	1.3, 6.1, 6.3, 6.4	

2/26/18	Power budget and power profiles, thermal modeling and thermal control		
2/28/18	Reaction wheel sizing; slew maneuvers	4.2, 6.5	HW3 assigned
3/5/18	**Launch operations:** launch profiles; launch environments; launch critical events; launch abort		
3/7/18	Launch vehicle staging		HW3 due
3/12/18	SPRING BREAK		
3/14/18	SPRING BREAK		
3/19/18	Planetary launch periods; launch windows	7.3	HW4 assigned
3/21/18	JPL Design Principles; Flight Project Practices; GSFC Gold Rules		
3/26/18	Cost estimation; earned value management; Review		HW4 due
3/28/18	Midterm 2		Midterm 2
4/2/18	**Space flight operations failures: causes and consequences**; Pillars of space flight operations		
4/4/18	Lewis Failure	Lewis Failure Report	
4/9/18	Mars Climate Orbiter failure	MCO Failure Report	
4/11/18	Mars Climate Orbiter failure		
4/16/18	Guest Lecture: Mars science operations		
4/18/18	Challenger failure	Challenger Failure Report	
4/23/18	Challenger failure		
4/25/18	Flight operations failures wrapup: crosscutting lessons learned		Term Paper Due

Disclaimer

This syllabus is subject to change, at the discretion of the instructor.